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Lyon Inc. -- Detroit, Mich.
Development
of
Deep Drawn - One Piece
High Performance
Rocket Motor Case
Army Cont. DA-20-018-ORD-23004
General Report #15

Copy No. 29

LYON INCORPORATED
DETROIT, MICHIGAN

General Report No. 15
for the period
December 10, 1961, through January 10, 1962
on

DEVELOPMENT

OF

DEEP DRAWN - ONE PIECE

HIGH PERFORMANCE

ROCKET MOTOR CASE

Submitted to:

U. S. Army Ordnance
Frankford Arsenal
Technical Supervisor - Mr. C. J. Porembski

INCORPORATED

ORDNANCE PRODUCTS DIVISION

MANUFACTURERS
OF
CARTRIDGE CASES · BOMBS · ROCKET MOTOR CHAMBERS
AND MISSILE COMPONENTS

13881 WEST CHICAGO BOULEVARD

DETROIT 28, MICHIGAN

January 10, 1962

U. S. Army Ordnance
Frankford Arsenal
Philadelphia 37, Pennsylvania

Attention: Mr. C. J. Porembski, Technical Supervisor

Subject: General Report No. 15 on the development of a deep drawn, one-piece high performance rocket motor case

Reference: Contract No. DA-20-018-ORD-23004, Article II -- Reports and Other Data

Gentlemen:

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This report summarizes the progress made during the period of December 10, 1961, to January 10, 1962, to develop improved monolithic rocket motor cases for 40" (and over) diameter solid propellant rockets.

The specific goals are the development of reliable motor cases with hoop-stress limits substantially in excess of 200,000 psi steel equivalent. The motor cases must be capable of being produced with reasonable ease on an industrial scale and their reproducibility proven by reliability tests at final full scale. The general objective is to be accomplished utilizing the Pershing 2nd stage motor case configuration.

I. Special Tooling - Material and Fabrication

(A) 40" Diameter Pershing 2nd Stage Motor Case -- Dwg. A1 and A2

1. Completed Die Assemblies

Fabrication of the hot cup, first draw, and second draw die assemblies was completed in the last report period. A description of their tryout is presented later in this report.

2. Third Draw Die -- No. E-20003

Fabrication of this die assembly was completed during this report period. The dimensional inspection of the component parts has been finished and the die is ready for tryout.

3. Fourth Draw Die -- No. E-20004

Delivery of the rough machined punch, the only remaining unfinished component of this assembly, was made during this report period. Final grinding and microfinishing are well underway and will be completed in time for the scheduled tryout date.

4. Fifth Draw Die -- No. E-20005

The rough machined punch has been delivered and submitted for final grinding and microfinishing. The finishing operations will be finished in time for the scheduled February tryout.

5. Sixth Draw Die -- No. E-20006

The rough machined punch has been delivered and submitted for final grinding and microfinishing. The finishing operations will be completed in time for a late February tryout.

6. Heading Die -- No. E-20007

Orders for the material and fabrication of this die assembly have been placed. The scheduled delivery will allow tryout during the early part of March.

II. Special Tooling - Tryout and Development - Phase I

(A) 40" Diameter Pershing 2nd Stage Motor Case - Dwg. A1 and A2

1. Hot Cup -- No. E-20000

Late in the last report period, tryout of the hot cup operation was started. A description of the operation and the methods used was presented in our last report (General Report No. 14). This development continued through the first days of this report period. By December 13, 1961, all of the 300-M blanks had been processed through the hot cup operation. Inspection of the cups revealed satisfactory conformance to the dimensional requirements of this stage of the processing.

2. Heat Treatment

Following the hot cup operation, the cups were given the following normalizing heat treatment:

1) Heated at 1725° F. for a period of 3 hours.
2) Discharged from high heat furnace and immediately transferred to a furnace at 625° F.
3) Cups were equalized at 625° F. and then held at 625° F. for 1 hour.
4) The temperature of the furnace and cups was then increased to 1000° F. and the cups were soaked at 1000° F. for 30 minutes.
5) The cups were then discharged from the furnace and allowed to air cool to room temperature.

As previously reported, test samples were processed with each cup in order to evaluate microstructure after heat treatment. The appearance of the structure after the hot cup operation is shown in negative numbers A-313 and A-314. This structure is that of an upper bainite. After the normalizing operation, the structure was that of a relatively coarse, acicular lower bainite and is illustrated in negative numbers A-315 and A-317. The total depth of complete and partial decarburization of the surface was found to be about 0.005". See negative numbers A-318 and A-319. This amount of surface decarburization is not detrimental since subsequent ironing operations will reduce this layer to a negligible value.

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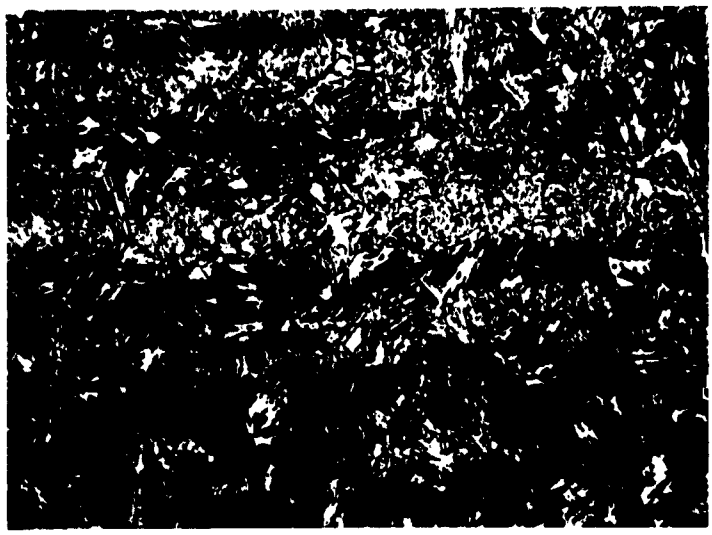

Mag: X100 Etchant: Nital
Neg. No. A-313

Material: 300-M
Operation: Test Sample from Hot Cup Operation

Remarks: Shows Microstructure of Upper Bainite

Mag: X500 Etchant: Nital
Neg. No. A-314

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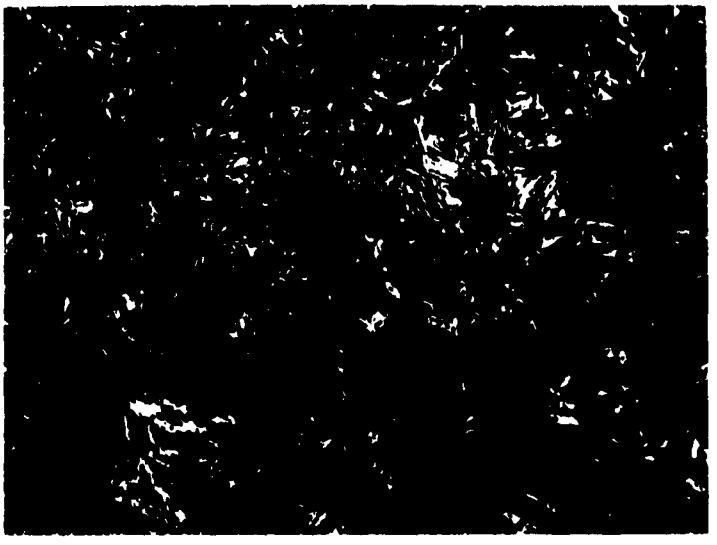

Mag: X100 Etchant: Nital
Neg. No. A-315

Material: 300-M
Operation: Test Sample after Normalizing

Remarks: Shows Microstructure of Lower Bainite

Mag: X1000 Etchant: Nital
Neg. No. A-317

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Mag: X100 Etchant: Nital
Neg. No. A-318

Material: 300-M
Operation: After Hot Cup and Normalize

Remarks: Shows extent of surface decarburization

Mag: X500 Etchant: Nital
Neg. No. A-319

The normalized cups were then subjected to the following isothermal treatment:

(1) Preheated in salt bath furnace at 1225° F. for 5 hours.

(2) Transferred to salt bath furnace at 1430° F. and held at temperature for 20 minutes.

(3) Transferred to salt bath furnace at 1225° F. and held at heat for a period of 24 hours, discharged from furnace, buried in insulator, and slow cooled to room temperature.

As can be seen in negative numbers A-354 and A-355, this treatment resulted in the completely spheroidized structure which is the optimum structure for cold forming ultra high strength low alloy steels. After completion of the isothermal treatment, cup AT-1 was selected for metallurgical analysis. This cup will be sectioned and a complete metallurgical analysis made. The results of this study will be presented in a future report.

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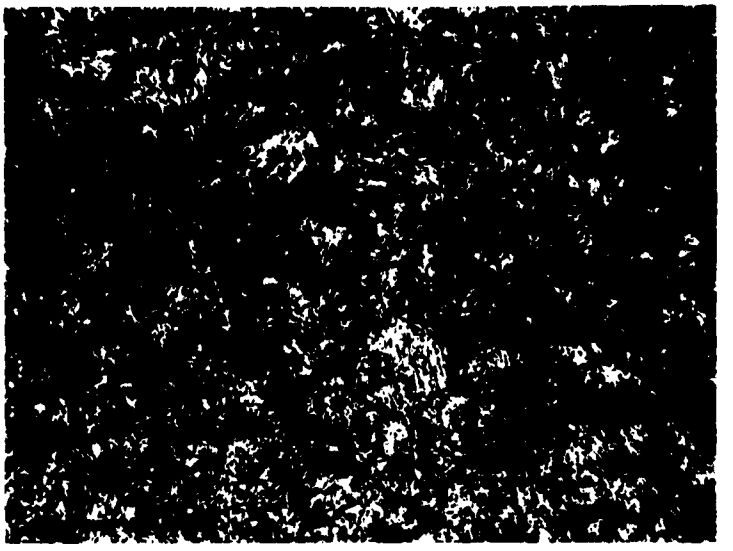

Mag: X100 Etchant: Nital
Neg. No. A-354

Material: 300-M
Operation: Test Sample after Spheroidization

Remarks: Shows completely spheroidized structure

Mag: X1000 Etchant: Nital
Neg. No. A-355

3. First Draw Die -- No. E-20001

During the period that the cups were being isothermal treated, the first draw die assembly was installed in the press and carefully aligned. After a thorough checkout of the installation, the assembly was ready for tryout. As soon as the first cup had been isothermal annealed, it was cleaned and coated for the first draw. In this operation, the overall diameter of the case is slightly reduced and the sidewall thickness is reduced by approximately 30%. The decrease in wall thickness results in an increase in overall length.

The die assembly performed smoothly and as expected. The ironed sidewall possessed a very smooth finish and was free of scoring or die marks. Following the cold reduction, the case was process annealed at 1250° F. for 1 hour. Subsequent dimensional inspection revealed that the 1st draw conformed to the dimensional requirements of this stage of the processing.

4. Second Draw Die -- No. E-20002

After the first few pieces had been processed through the first cold draw, the second draw die assembly was installed in the press and carefully aligned. During this operation, the overall diameter is reduced and the sidewall receives a partial iron in the region adjacent to the forward dome.

After cleaning and coating, the first chamber to receive this operation was placed on the punch and formed. Subsequent inspection revealed that the part conformed satisfactorily to the dimensional requirements of this stage of processing.

III. Alloy Investigation

(A) Strain Hardening Tests

1. The results of tests to determine the strain hardening characteristics of the 6% Al-4%V titanium alloy, the 6% Al-6%V-2% Sn titanium alloy, and the 18% Ni-7% Co-5% Mo alloy were presented in General Report No. 14. During this report period, metallographic examinations have been made of each specimen used in establishing the strain hardening curve. Photomicrographs were taken of only a few of the reduction stages to illustrate the effects of deformation.

2. 6% Al-4%V Titanium Alloy

As reported previously, only limited reduction was possible with this alloy at room temperature. At a temperature of 1000° F., however, the alloy possessed much greater ductility and could be reduced with considerably less tonnage. The following photomicrographs, negative numbers A-212, A-213, A-220, A-221, A-278, A-279, A-274, and A-275, illustrate the effect of the designated amounts of deformation on the microstructure of the alloy.

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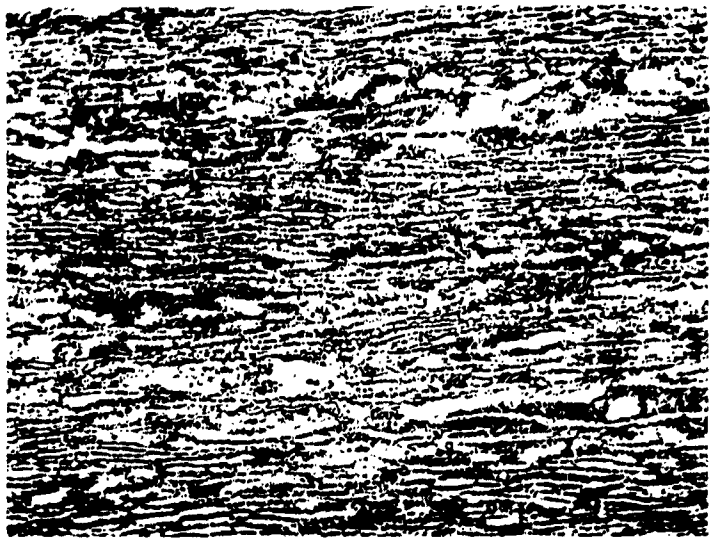

Mag: X250 Etchant: Kroll's Reagent
Neg. No. A-212

Material: 6Al - 4V Titanium Alloy
Condition: As annealed - no deformation
Hardness: Rockwell "C" Scale 35.0

Mag: X500 Etchant: Kroll's Reagent
Neg. No. A-213

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Mag: X250 Etchant: Kroll's Reagent
Neg. No. A-220

Material: 6Al - 4V Titanium Alloy
Condition: Cold compressed 21.3% in single reduction
Hardness: Rockwell "C" Scale 36.0

Mag: X500 Etchant: Kroll's Reagent
Neg. No. A-221

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Mag: X250 Etchant: Kroll's Reagent
Neg. No. A-278

Material: 6Al - 4V Titanium Alloy
Condition: Compressed 17.1% at 1000° F. in single operation
Hardness: Rockwell "C" Scale 36.0

Mag: X500 Etchant: Kroll's Reagent
Neg. No. A-279

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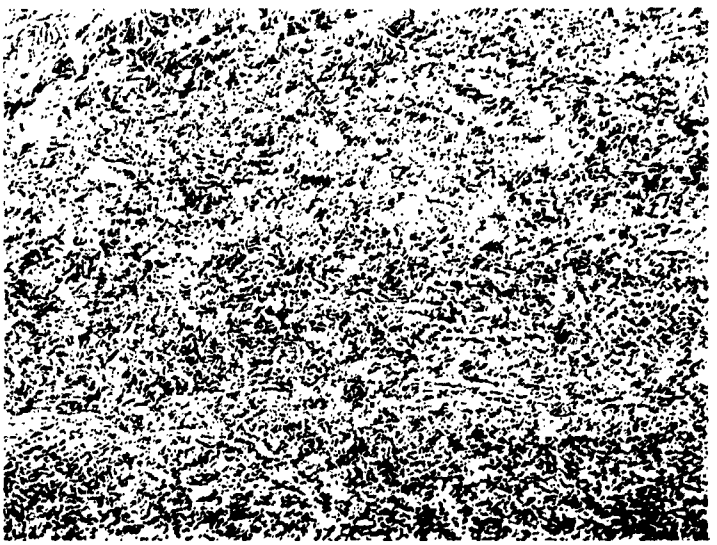

Mag: X250 Etchant: Kroll's Reagent
Neg. No. A-274

Material: 6Al - 4V Titanium Alloy
Condition: Compressed 48.2% at 1000° F. in single reduction
Hardness: Rockwell "C" Scale 37.0

Mag: X500 Etchant: Kroll's Reagent
Neg. No. A-275

3. 6% Al-6% V-2% Sn Titanium Alloy

Again only limited reductions were possible at room temperature. No tests were performed at elevated temperatures with this material. The following photomicrographs illustrate the effect of deformation on the microstructure of the alloy. See negative numbers A-222, A-223, A-232, and A-233.

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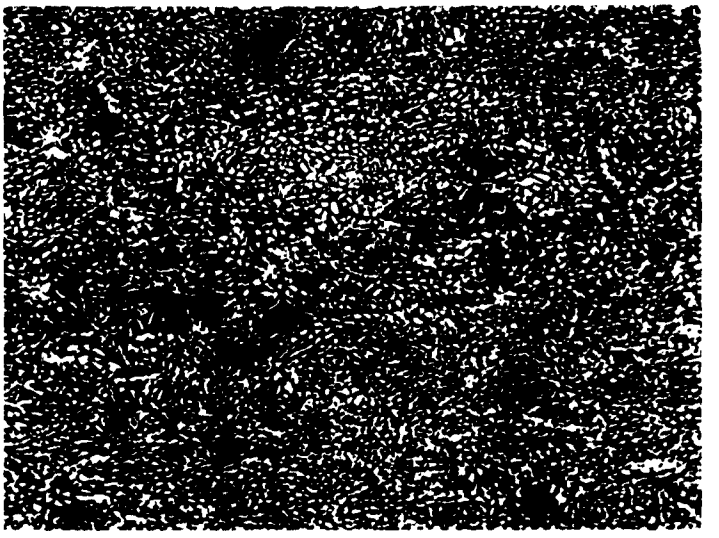
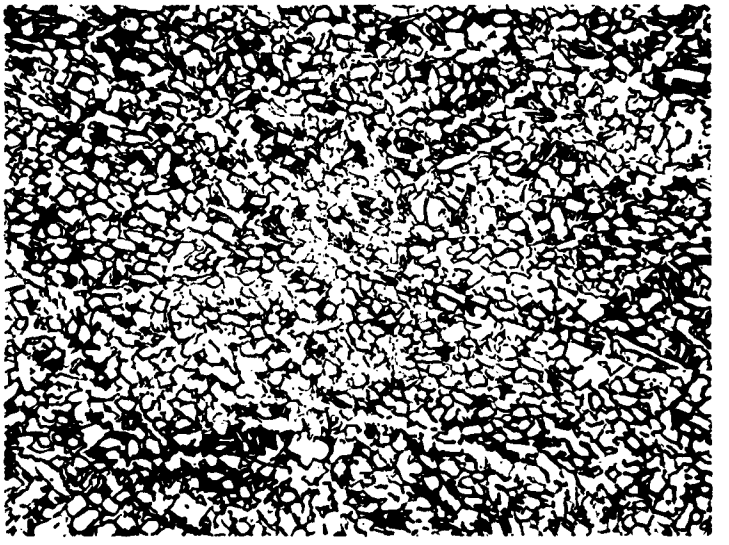


Mag: X250 Etchant: Kroll's Reagent
Neg. No. A-222

Material: 6Al-6V-2Sn Titanium Alloy
Condition: As annealed - No Deformation
Hardness: Rockwell "C" Scale 36.0



Mag: X500 Etchant: Kroll's Reagent
Neg. No. A-223

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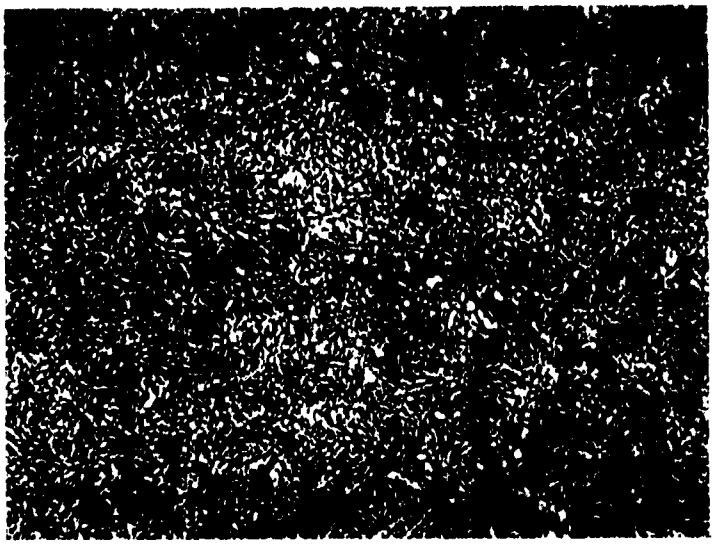
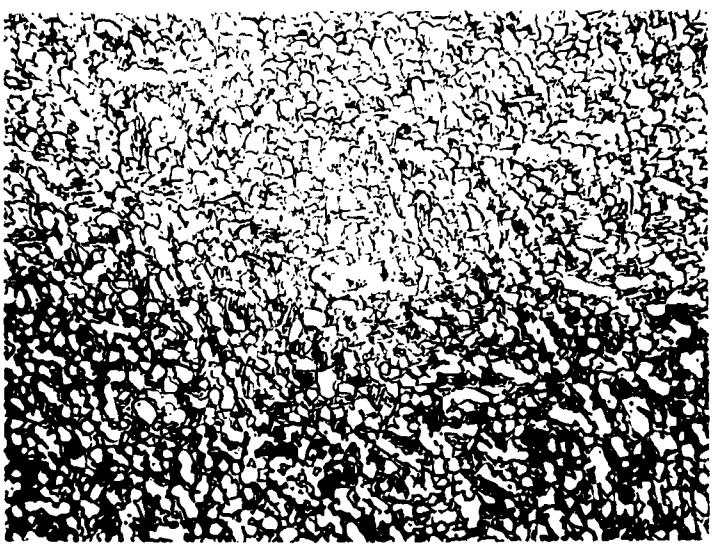


Mag: X250 Etchant: Kroll's Reagent
Neg. No. A-232

Material: 6Al-6V-2Sn Titanium Alloy
Condition: Cold reduced 28.0% in single reduction
Hardness: Rockwell "C" Scale 38.5



Mag: X500 Etchant: Kroll's Reagent
Neg. No. A-233

4. 18% Ni-7% Co-5% Mo Alloy

The following photomicrographs, negative numbers A-320, A-321, A-324, A-325, A-326, A-327, A-328, and A-329, illustrate the effect of deformation upon the microstructure of this material.

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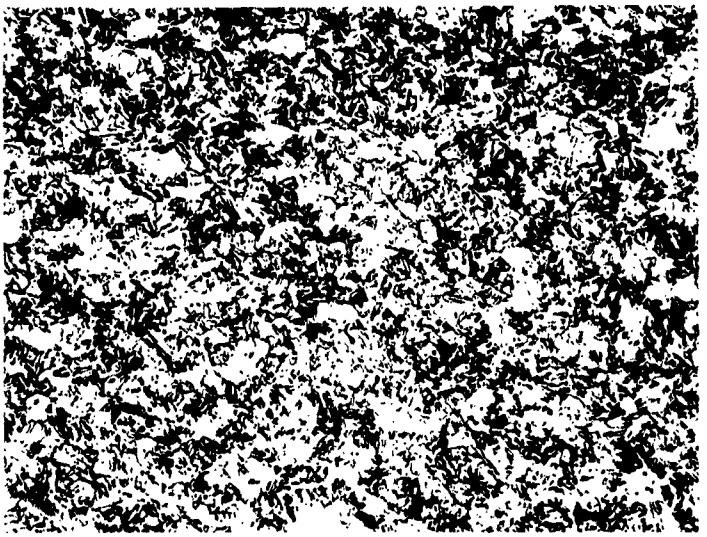
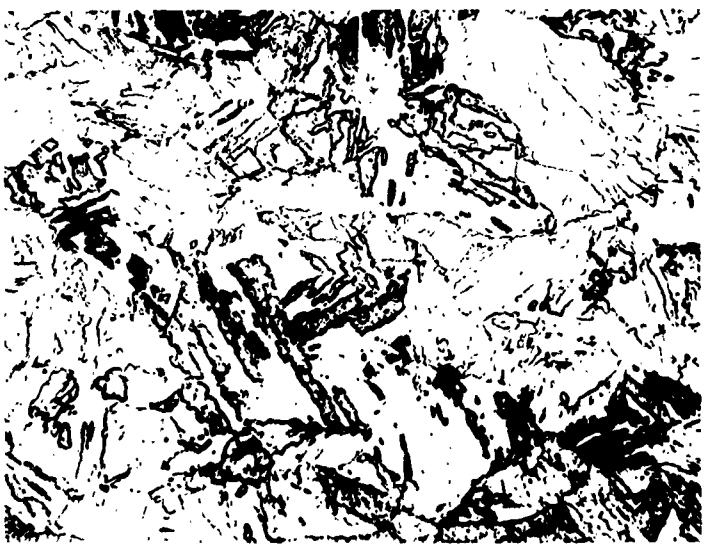


Mag: X100 Etchant: Ferric Chloride
Neg. No. A-320

Material: 18Ni-7Co-5Mo Marage Alloy
Condition: As annealed - No deformation
Hardness: Rockwell "C" 32.0



Mag: X500 Etchant: Ferric Chloride
Neg. No. A-321

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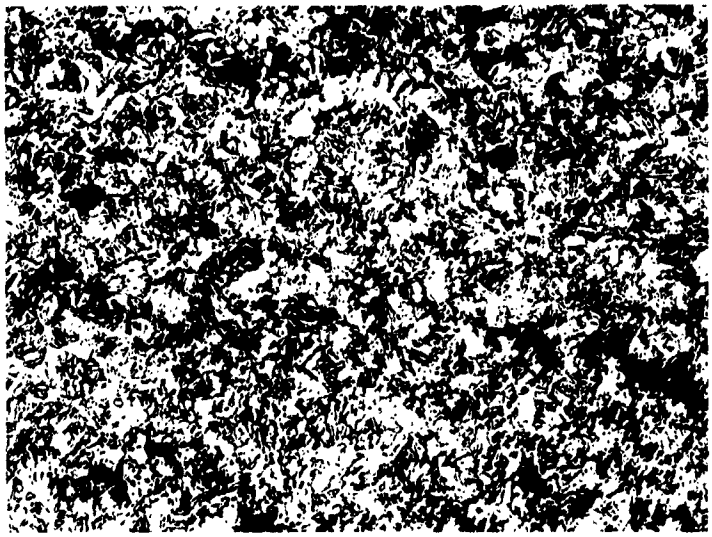
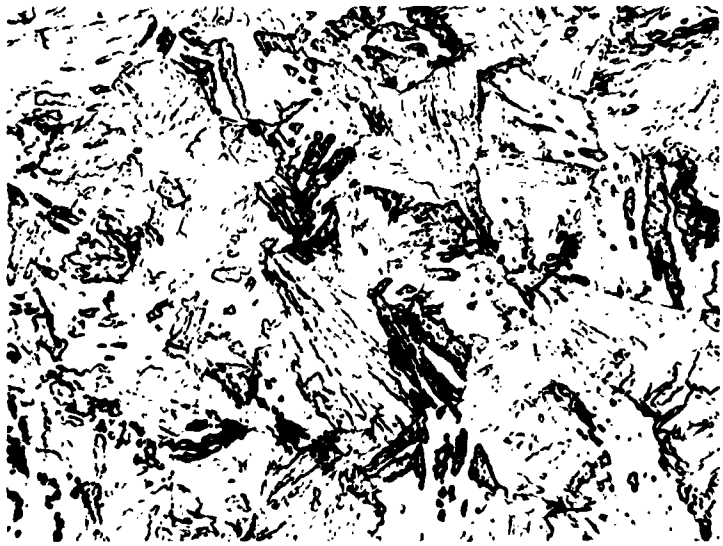


Mag: X100 Etchant: Ferric Chloride
Neg. No. A-324

Material: 18Ni-7Co-5Mo Marage Alloy
Condition: Cold reduced 14.0% in single reduction
Hardness: Rockwell "C" 33.5



Mag: X500 Etchant: Ferric Chloride
Neg. No. A-325

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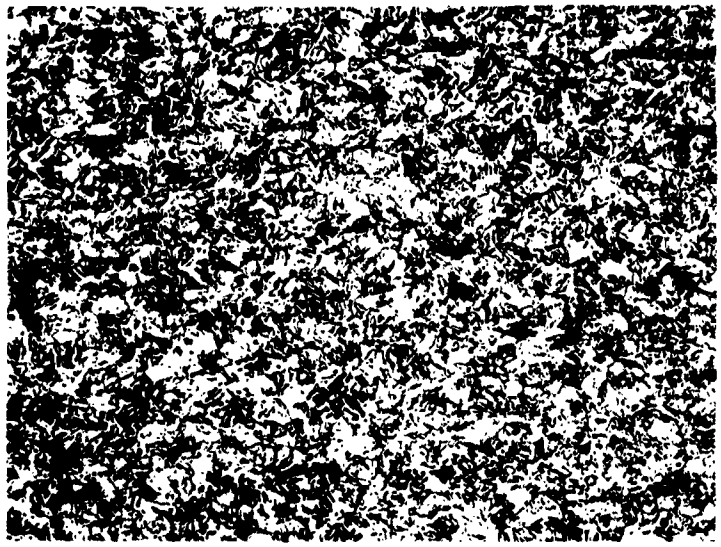
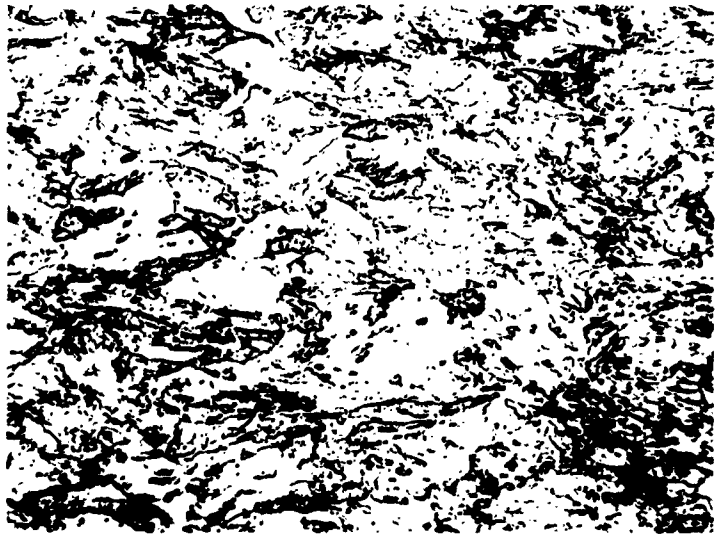


Mag: X100 Etchant: Ferric Chloride
Neg. No. A-326

Material: 18Ni-7Co-5Mo Marage Alloy
Condition: Cold reduced 44.0% in single reduction
Hardness: Rockwell "C" Scale 36.5



Mag: X500 Etchant: Ferric Chloride
Neg. No. A-327

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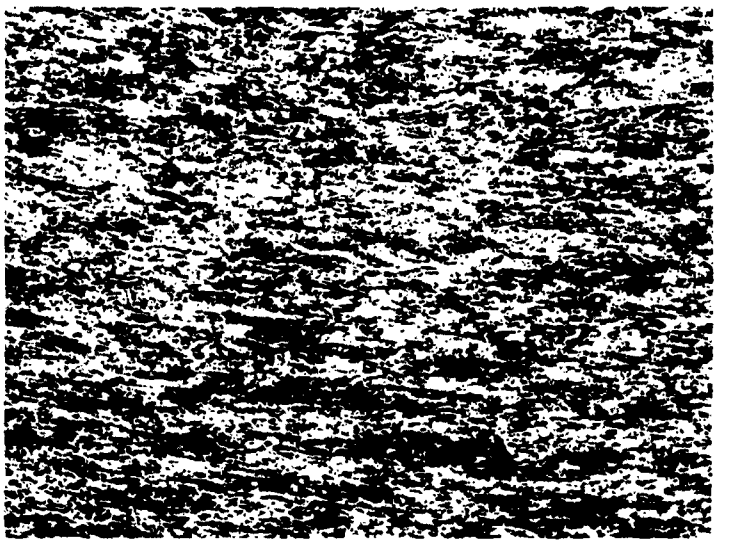

Mag: X100 Etchant: Ferric Chloride
Neg. No. A-328

Material: 18Ni-7Co-5Mo Marage Alloy
Condition: Cold reduced 62.0% in single reduction
Hardness: Rockwell "C" 38.5

Mag: X500 Etchant: Ferric Chloride
Neg. No. A-329

5. The results obtained indicate that the 18% nickel alloy should behave similarly to the 20% nickel alloy when cold deep drawn. Both of the alpha-beta titanium alloys are capable of only limited reduction at room temperature.

(B) Reduction and Anneal Tests

Simulated reduction and anneal tests have been made on the all beta titanium and the 18% nickel alloys. During these tests, small cylinders were given the same reductions and annealing cycles as would be received with the 40 inch tooling. At the completion of testing, a sample representative of each of the six reductions, before and after annealing, was available. In all cases, the surface appearance of the samples was satisfactory and free of cracks. The results of hardness and metallographic tests upon these samples will be presented in a future report.

(C) Sub-Scale Drawing Tests -- All Beta Titanium Alloy

During this report period, the seven sub-scale machined pancakes of all beta titanium alloy were subjected to the hot cup operation. These pieces possessed the following forging history prior to hot cupping:

(1) Small billets, 3" dia. x 3" high, were upset forged at 1750° F. into flat round pancakes approximately 7" dia. x 1/2" thick.

(2) The rough pancakes were then solution treated at 1450° F. for 30 minutes followed by air cooling.

(3) The rough pancakes were machined to 6.575" dia. x 0.325" thick.

The seven blanks were then cupped at temperatures ranging from 1600° F. to 1400° F. in order to evaluate the effect of temperature upon the cupping operation. Heating was done in the carbonate salt described in General Report No. 14. Although the material could be cupped satisfactorily at all of the temperatures investigated, better surface finish conditions were obtained near the low end of the temperature range. A more complete report of the hot cupping of this material will be presented in a future report.

The sub-scale cups are now being prepared for subsequent first and second cold draws. These operations should be completed within the next report period. Following the second draw, the sub-scale cases will be sectioned for metallurgical analysis.

Sincerely yours,

LYON INCORPORATED

Wayne A. Martin

Wayne A. Martin, Director
Lyon Ord. Res. and Mfg.

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